# CONCRETE: REDEFINING AN IDENTITY

by

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Second only to water, concrete is the most widely used substance in the world. It is a mixture, at the most basic level, of aggregate, cement, and water that when cured, has incredible structural capabilities. Concrete is a material commonly used for its most prominent characteristic: compressive strength. Because this component of its identity is so strong, it often dominates over concrete's other attributes. While designers tend to embrace concrete and its many attributes, the general public conversely tends to prefer other materials to concrete when offered a choice. Despite prominent examples of concrete being used to its full potential, it still suffers under a bad reputation. Those that don't like concrete often view it as cold, hard, aggressive, gray, or just boring. Surprisingly, many people don't even know how concrete is made. It is an incredibly malleable material for which, in recent years, new technologies have only scratched the surface for exploring ways to push its limits. Concrete's broad applications as a material and misunderstood history have resulted in a lack of an established identity that successfully spans disciplines. This thesis explores the trajectory of concrete as a material and the ways in which its physical properties, application, and treatment largely go unrecognized and are commonly misunderstood by non-designers, resulting in this inconsistent and confused identity.

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# Table of Contents

# List of Accompanying Materials

Book – Concrete: Redefining an Identity

## Introduction

Concrete is the second most consumed substance on earth outpaced only by water at 7.5 billion cubic meters per year.[1] There are many factors contributing to the reason why concrete is used so much including its water resistance, malleability, relatively low cost, and generally abundant ingredients. Above all else, it is common for concrete to be largely acknowledged for its compressive strength as a structural material. This prominent characteristic often dominates over concrete's other attributes. Despite its high usage and prominent examples of it being used to its full potential, a common view among non-designers is that concrete is drab, cold, aggressive, or just boring when compared to the multitude of other material options. Those who work in the building industry often acknowledge the awesomeness that is concrete as well as its potential as a material. This thesis stemmed from an observation of the disconnect in perception of concrete between the industry folk and non-specialists. Specialization in any field naturally divides those with knowledge and passion from the non-specialists, but there seems to be an even larger gap when dealing with concrete. There are other materials such as wood, brick, and stone that, though specialized, still enjoy a widespread appreciation for their use and recognition/general understanding of their individual assets. Unlike these materials, concrete, as a whole, doesn't occur in nature. Because it is highly processed, there is a mysterious aspect to it. Concrete is more

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[1] Koren, Leonard, and William Hall. Concrete. London: Phaidon, 2012. Print.

challenging to promote due to the discrepancies in perception that have developed between designers and non-designers.

The common misuse of the term cement as synonymous with concrete points to the disconnect I'm addressing. In simple terms, cement, when combined with water, is the glue that holds concrete together. Concrete is the complete mixture. For such a broad group to misunderstand a key distinction of a relatively simple substance that is so widely used around the world is astonishing. So why is it that such a widely used material can have such a misunderstood identity? The basic makeup of a material is fundamental in understanding how and why a material is and should be used. Concrete has an expansive portfolio, but still battles a bad reputation for being unexciting, and unoriginal. Unlike other common building materials, concrete's identity is inconsistent across disciplines. This confusion can partly be attributed to concrete's material structure as one of diverse malleability and therefore expansive applications. Concrete's initially fluid state requires it to be cast, but unfortunately, this vital part of its creation process is rarely approached in creative ways. Instead, concrete's use as a cheap material for structural members often overshadows such potential. Structural members have previously been modeled from the standard steel I-beams and square concrete columns. Not only does concrete have the ability to be formed into more efficient shapes for transferring stress loads, but concrete as a finish material, has vast potential beyond its commonly plain, smooth, gray surface. The unrecognized and misunderstood aspects of concrete's identity have made it difficult for non-professionals to engage an interest in the material. This thesis investigates some of the ‘whys’ related to this gap between the designers and non-designers, which in turn has lead to understanding the ‘whats’ of concrete’s identity.

There are many factors that have contributed to the gap, but I argue that concrete’s lack of a consistent identity across disciplines leads to confusion about its potential and purpose, which is the primary hindrance to achieving widespread appreciation for the material. The few designers and engineers who have achieved widespread success for primarily concrete designs are those who test its limits as a material. When employed at its full potential, it often expresses something of the process for which it was made or formed as well as its extraordinary capabilities. Concrete as a processed material, does not occur naturally. Combine that characteristic with its prevalent use in mega projects, and it is easy to understand the difficulty of non-designers to relate to such a material that commonly lacks a tangible attraction at a human scale.

This thesis intends to analyze and observe a key perspective previously unexplored. The analysis is intended to contribute valuable insight into concrete’s trajectory as a building material and how understanding that evolution can greatly influence its future. The designer/non-designer gap has not been probed in the field of architecture or other professional design practices. I hope that this thesis provokes further discussion and study of the existing gap, while addressing the previously disconnected audiences by peaking an interest for the material.

## On the Views of Concrete

The popular criticisms of concrete and the misinformed aspects of the material are crippling its reputation and defining a narrow-minded identity. The biggest criticisms surround the topics of concrete's physical appearance and sustainability. The most significant misinformed aspects of concrete's identity include: how it's made, its history as a material, and its capabilities both through high performance as well as creative exploration of the material. Much of my research verified the existence of these common negative influencers by consistently making attempts to correct the misinformed knowledge and promote the versatility of the material that is rarely utilized.

The components of concrete's mixture are chemically complex, but are broken down into simple terms by William Hall and Leonard Koren in *Concrete*, as well as Adrian Forty in his essay, "The Material without a History." These are only two of many intellectuals who recognize the sometimes staggering complexities that are inherent to this processed material, but who break down the process into the most basic components.

Reese Palley discusses the true origins of concrete in his book, *Concrete: A Seven-Thousand Year History* by calling out notable historic discrepancies for the material's beginnings, and narrating a true material history. Kyle May discusses the lasting effects Brutalism has had on the public's perception of the material in his collection of essays in *Brutalism*. Concrete's origin and Brutalist era are only two of the major events in concrete's history that need to be readdressed. Despite the importance of understanding the origins of a material as part of its identity and purpose, the truth regarding concrete’s origin is seldom known. The Brutalist era is commonly misunderstood as well and needs to be discussed.

Concrete’s commonly criticized physical appearance is defended by many, including Michael Kalan, Adrian Forty, and Graham True to name a few. Each of these writers not only defend the natural physical attributes of the material, but they go on to provide their readers with many examples of various options available to stray from the conventionally gray, smooth, flat surface of concrete.

Lastly, the discussion regarding concrete’s level of sustainability can be found in most books addressing material options and the related energy for each of those materials. The common criticisms surrounding concrete’s lack of greenness stem from accurately proclaimed high levels of energy input required to produce the substance. The concrete industry is beginning to explore options motivated by these greater concerns and has been developing high performance concretes that challenge traditional understandings of concrete’s identity. Instead of simply attacking the material’s currently unsustainable production practices, it is important to comprehend the vast scale at which it is being used around the world and realize that concrete cannot be completely removed from production on a short timeline. Therefore, the material’s currently high levels of energy consumption need to be seen as an opportunity for improvement and innovation.

The lack of appreciation for concrete was not always the result of a distinct separation between the designers who work with it and non-designers. Various experienced designers had their own negative opinions of concrete. Having such famous architects like Frank Lloyd Wright proclaim concrete as a "mongrel material [that was] neither one thing nor another"[2] only encouraged and promoted its prolonged acceptance as an inferior material. Such a respected architect publicly expressing this strong aversion toward a material influenced a huge audience. Other intellectuals of the early 20th century expressed concerns for the rising use of concrete. British postwar committees worried about concrete and expressed how "we cannot ask our population to lead a full and happy life in such surroundings"[3] and Sir Nikolaus Pevsner believed that "concrete with all the shuttering marks can never be attractive"[4]. Many of these opinions were held during the Brutalism era. These feelings of resistance and apprehension soon became popular opinion.

Brutalism peaked in the 1960s and 70s after being catalyzed in Britain by the widespread efforts to reconstruct with public housing projects after WWII. [5] The massive scales for which these housing projects began made concrete the practical material choice. By using concrete as the primary building material, such mega projects became affordable. Brutalism is often analyzed from the

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[2] In the Cause of Architecture VII: The Meaning of Materials—Concrete" [1928], reprinted in F.L. Wright, Collected Writings, vol. 1, ed. B.B. Pfeiffer [New York: Rizzoli, 1992], 297-301.
[3] Ministry of Works, Great Britain, Post War Building Studies, no. 18, The Architectural Use of Building Materials, 1946, paragraph 278.
[4] The Buildings of England, London 2: South [Harmondsworth, Middlesex: Penguin Books, 1983], 353.
[5] Kalan Michael Contreras, "Revisiting Brutalism: The Past and Future of an Architectural Movement" [Masters diss., University of Texas at Austin, 2013], 3.

perspective of the surface treatments of cast-in-place concrete, but the primary element of Brutalist design was the use of precast because it “promised the economies of scale through Fordist mass production.”[6] The ability to produce at massive scales made the primary employment of the Brutalist era belonging to public buildings like administrative headquarters, schools, libraries, and public housing projects.

It is important to clarify Brutalism’s classification as “a philosophy too often mistaken as a style.”[7] This philosophy was based on a belief of the importance of exposing the truth of the material and employing the programming of the design to guide user actions rather than users’ needs dictating design. Such disconnected designs of the time has resulted in “Brutalism arguably produc[ing] some of the world’s least popular public buildings.”[8]

## On Concrete’s Identity

What separates concrete from other common building materials can be attributed to many factors, but one significant factor is that concrete must be created. This is unlike other common building materials such as stone or wood that are repurposed or modified. As a result, there is a certain foreign nature about concrete for those who don’t know how it’s made. Materials like stone and wood are easy for users/observers to understand and connect with at the human scale because they can comprehend where they came from, and to a

[6] May, Kyle, and Julia van den Hout. 2013. Brutalism. [Brooklyn, N.Y.: CLOG], 47.
[7] Ibid, 65.
[8] Ibid, 5.

certain extent, how they were formed. Those natural materials have set identities in the sense that they have uses that are distinctly associated with their physical attributes. Concrete's malleability and advanced structural capabilities conversely allow it to be used for almost anything. As a result, concrete has failed to distinguish a consistent identity in the material world.

Having a distinguished identity with inherent boundaries allows for people to appreciate when those boundaries are being broken. Natural materials like wood and stone have distinct attributes and physical capabilities that result in areas of usage where they are strong and areas that are simply not practical. That is not to say that these materials are never used in unconventional ways. Instead, the instances when these materials stand out from their traditional uses can be appreciated by a much broader audience than when concrete breaks its own barriers of identity. Because the perception of concrete across audiences is inconsistent, it becomes difficult to distinguish instances of innovation.

Adrian Forty goes as far as denying that concrete is even a material, but that it is a process and that "it's the ingredient of human labor that produces concrete"[9]. Forty explains that the process of creating and forming concrete can be much more prominent in its appearance than other materials such as stone and timber.[10] Because concrete inherently must be created instead of used in a natural state, its capabilities are still being discovered. Concrete has the ability

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[9] Forty, Adrian. "The Material Without a History," in Liquid Stone: New Architecture in Concrete, ed. Jean-Louis Cohen and G. Martin Moeller, Jr. [New York: Princeton Architectural Press, 2006], 37.
[10] Ibid.

to express its creation process in many ways and it is often easier to acknowledge and appreciate as a material when this process is presented to its user. Le Corbusier coined the term béton brut, meaning “a concrete whose surface bears the imprint of the molding process.”[11] These imprints are commonly shown from board formwork or the conical voids left unfilled from snap ties removed after the concrete has set. The fact that an entire term was coined to describe this method of finishing indicates the important influence of that visual experience on its observers.

Perhaps it is the tangibility of a material that makes it more appealing to its users or observers. Concrete, in its most commonly used form, has a consistently smooth finish that spans large areas with little variation or even any indication of seams. Concrete is often used at such large scales that it can surpass its likability at the human scale very quickly. Wood and stone have characteristics that require intermediate supports, seams, connection points, etc. that all reveal attributes of their physical capabilities. Concrete is a material that begins in a liquid state that then becomes a hard substance. This allows it to hide its creation process very easily. Some could critique that the fact that concrete’s capability to have such expansive, uninterrupted surfaces is what displays its inherent capabilities as a material. The issue with that statement comes with the difficulty people have relating to and thereby appreciating such massive scales. Commonly using concrete in such mega projects makes it

[11] Legault, Rejean. “The Semantics of Exposed Concrete,” in Liquid Stone: New Architecture in Concrete, ed. Jean-Louis Cohen and G. Martin Moeller, Jr. [New York: Princeton Architectural Press, 2006], 47.

especially challenging for non-designers, who are not familiar with concrete, to understand the material and therefore appreciate its usage.

Concrete must be cast to be useful. Casting is when a material, due to its initially liquid state, is poured into a mold to achieve a finished shape. Recognizing the immense opportunities that come with such a moldable material is vital in understanding its identity and allowing for those capabilities to be capitalized upon.

Concrete's malleability should become the driving force behind its identity. If concrete is used in ways that present a unique shape that is achieved through its solid-liquid nature, it will become apparent that no other material could replicate such a form. This should not limit every form to appearing fluid, but should encourage further exploration of concrete's fluidity in its youth state. Nonetheless, this presentation of malleability, whether through form, finish, or function, should reflect concrete's myriad strengths as a material. While this common material has been battling its bad reputation for a huge part of its existence, it is time to honor its truly awesome capabilities.

## Concrete's Confused History

From the common misuse of the word cement when referring to concrete to its incredibly misinformed history, concrete is still struggling to develop a widespread, consistent identity. It is thought by many that the origins of concrete date back to the time of the Romans. In reality, concrete dates back to Egypt and the time of the great pyramids.

The Pyramids were built from a material comparable to cast-in-place concrete blocks. For years, school children have learned that the pyramids of Giza were made of solid limestone blocks taken from local quarries. Only recently has this idea been refuted. In 1974, Joseph Davidovits established his own research organization, the Geopolymer Institute of Saint-Quentin, to investigate the idea of the pyramids actually being made of limestone concrete.[12] Joseph Davidovits developed eight points of evidence that support the notion that they are actually built from concrete rather than solid limestone.

1. Almost none of the pyramid blocks match the Giza bedrock chemically or mineralogically.
2. Pyramid blocks don’t contain any strata, which should be present in the local limestone.
3. Geochemical analyses show that the properties of the blocks match at least 20 different Egyptian quarries, not just local bedrock.
4. There was standardization of block sizes, which wouldn’t be necessary if they were hand carved, but would be logical if they had been cast.
5. Strata and defects in solid limestone would prevent perfect carving dimensions.
6. Realistically, if the builders used copper tools as documented, it would have taken way longer than the 20-year span to carve all of the stones.
7. There should have been at least some failure blocks due to the required precision, but there is no evidence of unused blocks in the area.

[12] Palley, Reese. Concrete: A Seven-Thousand-Year History [New York: Quantuck Lane Press. 2010], 18.

8. Pyramid blocks are 20 percent lighter than the local bedrock limestone. Cast blocks contain air bubbles and are always lighter.[13]

This idea is still a highly debated explanation in the archaeology world, but more and more archaeologists are signing onto the idea due to the strong supporting evidence. Davidovits is not the only person to explore this groundbreaking theory. MIT professor of material sciences, Linn Hobbs, has been exploring the use of limestone concrete mixtures with her students as well.[14] The knowledge of concrete having been discovered in the times of the pyramids of Giza was lost or misunderstood for years most likely due to the common protection of such technical information by the kings and royalty of the time.[15]

## On The Transition to Modern Concrete

What would be described as concrete today is something very different from the oldest forms of concrete. In fact, “no other technological discovery has had so many seemingly accidental starts and just as many unexplained disappearances”[16] over the course of its development. Despite its long history as a building material, what would be considered modern day concrete is relatively young. From Egypt to Rome and Asia Minor, it was common for the techniques of using concrete to be reserved for the knowledge of the elites,

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[13] Palley. Concrete: A Seven-Thousand-Year-History, 19.
[14] Nickerson, Colin. “Did the Great Pyramids’ builders use Concrete?” The New York Times 23 April, 2008. Nytimes.com. Web. 19 Jan, 2014.
[15] Palley, Concrete: A Seven-Thousand-Year-History, 41.
[16] Ibid, 41.

often those of religious standing.[17] As a result, it was common for that knowledge not to be passed on to laymen. During concrete's early years, it "was being used merely to enhance existing architecture rather than becoming the agent for an entirely new architecture."[18] The desire to explore its capabilities as a building material came much later.

Modern day concrete's evolution began shifting in the 18th and 19th centuries. There were a few key discoveries that catalyzed its development. The three most significant advances in concrete technology were the development of hydraulic lime, Portland cement, and ferro-cement. Hydraulic lime was developed in 1756 by John Smeaton and was the first instance where concrete could cure under water. Portland cement was conceived by Joseph Aspdin in 1824 and is still one of the most commonly used cements in concrete. Lastly, ferro-cement, or reinforced concrete, was developed by Joseph-Louis in 1844.[19] Reinforced concrete particularly revolutionized the industry. The first building made with reinforced concrete was later completed in 1893.[20] Concrete, as thought of and used today is the product of only a little over a century's worth of exploration and experimentation. Admixtures, which can be credited for the majority of concrete's versatility in terms of strength, color, and

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[17] Ibid, 24.
[18] Ibid, 175.
[19] Palley, Concrete: A Seven-Thousand-Year-History, 44.
[20] Ibid.

chemical properties, are an even newer addition to the world of concrete and have only been used for the last 40-50 years.[21]

## Methods

This section lays out the methods used throughout my research process. It will walk through the research question and the multifaceted approach to answering that question on various levels, as well as the methods used for understanding the gathered information. From there, it will go on to explain how the methods of understanding the information led to the primary element of this thesis, which is a book intended to address the research question and form a product that will prove useful for the field of architecture and other related fields.

First Research Question: Why is there such a large disconnect between designers and non-designers in their understanding of an appreciation for concrete?

Research: The vital first step was to understand the existing literature from various sources. I did this by first exploring written sources based on a few questions: Why is concrete so widely used as a material? What does the future of concrete look like? What is the real timeline of concrete's history? and What are the environmental implications of concrete and its production? Research topics developed from those questions and provoked further exploration of the: History of the material and how it has evolved over time in terms of use, make-up, and general identity; Physical characteristics of the material and what it's

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[21] Mehta, P. Kumar. Concrete: Structure, Properties, and Materials [New Jersey: Prentice-Hall, 1986], 249.

strengths and weaknesses are, both in terms of structural and visual characteristics; Process of creating concrete and the various approaches and techniques, and the flexibility of the guiding rules associated with each; and Popular opinions of the material and the catalyzing events that caused those widespread views.

Interpreting the Information: After collecting and reviewing the information, the research was reallocated by topic into 5 categories: Questions, History, Structure, Formwork, and Opinions. From there I was able to draw connections between elements and begin to answer the more specific questions that arose. Through my analysis, I observed that concrete's identity as a material, due to its malleability and advanced structural capabilities, does not have distinguished boundaries that could help define its identity.

Second Research Question: How can concrete's confused identity be re-established in order to close the gap between designers' view of the material and the popular negative opinions.

Development of the Book: Investigating the second research question catalyzed the development of the book. The second question led to researching the various ways concrete can be used and explored as a material. The previous topic categories were used as initial guidance for image searches until they developed into the final categories in the book: How It's Made, Roots of a Bad Reputation, A True History, Deceptive Malleability, Finishing Possibilities, An Artist's Interpretation, and High Performance. These images became the structure of the book with each image representing a relevant aspect of concrete's identity.

The book synthesizes the research and presents it in a manner that is intended to appeal to broad audiences of varying levels of knowledge and interest. By addressing a broad audience, the book will be aiding to bridge the gap. The book would be a great addition to architectural courses like building construction and structures as a complimentary book to the dense technical information expressed throughout the course. The simplicity and variation of content would provide a refreshing balance of information. Multiple techniques were used to achieve appeal to an audience beyond the architectural field. The information on each page (or, in rare cases, group of pages) is self-contained to allow a casual reader to read the material in small sections. Each page's written information as well as graphic layout is tailored for the greater purpose of the book: to motivate a greater discussion amongst the architectural field and other related fields about concrete's identity, while at the same time reaching the other disconnected audiences and peaking an interest for concrete and its use as a common material.

The structure of the book rewards deeper study for those who are interested, while also connecting with the casual reader. On each page, there is a list of related topics with page reference numbers of up to five other pages in the book, creating an interconnected structure. Some pages highlight suggested external resources for more information regarding that page's topic. Timelines on select pages highlight relevant dates for that topic and sometimes highlight the ‘range of influence’ that certain events had on concrete’s history. Each category section’s introductory pages show the entire collection of dates from the pages contained in that section to better illustrate an overall relationship between events.

## Concrete and the Environment

Despite concrete’s already millennia-long history, the understanding of its uses continues to develop. There are different driving factors behind this evolution, but one of the most discussed topics today is the concern surrounding concrete’s environmental sustainability, or lack thereof. Concrete’s energy consumption is incredibly steep unless you consider its long life from cradle to grave. The length of time concrete remains productive exceeds that of most other materials. Despite its impressive life cycle, concrete is often criticized when compared to other common materials because of its high embodied energy. Embodied energy is “how much energy must be invested to mine/harvest/produce, fabricate, and transport a unit of building material.”[22] The problem is in the definition. While it is important to acknowledge the commonly high embodied energy of most concretes, this is an incomplete perspective because it does not take concrete’s impressive life cycle into account. I argue that the complete life cycle of a product should hold more weight when examined than its initial energy input.

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[22] Grondzik, Walter et al., *Mechanical and Electrical Equipment for Buildings*. (New Jersey: John Wiley & Sons, 2010), 35.

This would begin to explain one element of the current widespread use of concrete.

Concrete, unlike many materials, rarely requires significant transportation to a job site because most of the ingredients are found in excess almost anywhere. The element that leads to most of the criticism of concrete's environmental implications is the production of cement. Though it only accounts for 12 percent of the total weight of concrete, it's responsible for 94 percent of its embodied energy.[23] The pollutions created from some of the chemical admixtures also contribute to the already high $CO_2$ levels released from the production of cement. Other materials may have less pollution during production or the harvesting process, but have much shorter life spans. One must consider all such factors for a balanced comparison of embodied energy. The production of concrete at its existing levels of emissions cannot continue at its current trajectory. This is why there have been efforts to mitigate the negative effects on the environment.

The developing technologies geared toward the advancement of concrete have begun exploring high-performance concretes that often decrease the necessary volume of concrete, which in turn, lessens the carbon footprint. One alternative element in the mixture is the substitution of HVFA (high volume fly ash) for some of the cement volume. Using HVFA lowers the embodied energy of the concrete because it's replacing a certain percentage of the

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[23] Koren and Hall. Concrete, 45.

cement.[24] There are other advancements in efficiency that allow for an overall lower volume of material such as the newly developed concrete called Ductal, which is an UHPFRC (ultra high performance fiber reinforced concrete)[25] that is rivaling the use of traditional rebar reinforcement. Exploring the use of geopolymers is another advancement that has lead to incredible strides toward greener concrete. The first building made from geopolymers was built in 2013. Many advancements like these have only been developed within the past 10-15 years. Modern-day concrete is incredibly young and there still need to be major improvements in order for concrete to be thought of as a truly green building material.

Though concrete's current position on the sustainability spectrum leaves plenty of room for improvement, it is making noteworthy strides. If concrete can be redefined to incorporate concepts like 'innovative' and 'diversified' into its definition, its modern progression would greatly benefit. There are many lessons to be learned from concrete's history and the failed methods of approaching a material that is both strong and malleable. And while acknowledging the flaws of any material is important, it is time to look at concrete in a new light, to close the gap in both knowledge of and appreciation for concrete, a truly awesome material.

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[24] Ibid, 46.
[25] Bennett, David. Concrete Elegance One (London: Riba Publishing, 2006), 39.

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